

Health Impacts of Diesel PM Emissions: An Update

**November 19, 2009
Sacramento, California**



Air Resources Board

California Environmental Protection Agency

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Thank you Mr. Goldstene. Good morning, Madame Chair Riordan and members of the Board.

Today, we'll be giving you an update on the health effects associated with exposure to diesel particulate matter.

Presentation Overview

- Health effects of diesel PM
- Methodology for estimating premature deaths
- Control programs and PM trends

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First, we'll discuss the health effects of diesel PM, which are significant in California. To provide a more in-depth overview of the scientific literature, we have invited Professor Jonathan Samet, distinguished scientist with expertise in epidemiology, to discuss the evidence and present his perspective on the health effects of diesel PM.

Then, I will review our recent staff report on the methodology for estimating premature deaths associated with PM_{2.5} exposure, including the extensive peer review process the report underwent.

And finally, I'll summarize the Board's actions to reduce PM emission and show how the concentration of PM_{2.5} has been decreasing in California, and what challenges remain to meet California's clean air goals.

Health Effects of Diesel PM

- ARB and OEHHA evaluating diesel exhaust since 1989
- Listed as a toxic air contaminant in 1998
- Responsible for 70% of air toxics cancer risk
- Listing formed the basis of ARB's Diesel Risk Reduction Plan

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We have known for nearly 20 years that exposure to diesel PM may lead to adverse health effects. In 1989 ARB, and the Office of Environmental Health Hazard Assessment (OEHHA) began evaluating the toxic effects of diesel PM. In 1998, the Scientific Review Panel endorsed ARB's and OEHHA's report and risk assessment on diesel PM, and it was then listed as a toxic air contaminant. The staff report concluded that diesel PM may cause an increase in the likelihood of cancer.

Staff also calculated the cancer risk associated with air pollution and showed that diesel PM is responsible for about 70% of the total ambient air toxics cancer risk. The body of scientific literature on the health effects of diesel PM formed the basis of ARB's Diesel Risk Reduction Plan, and support from the literature continues to grow.

Diesel PM Also Linked to Premature Death

- Diesel PM is a component of ambient PM_{2.5}
- Ambient PM_{2.5} associated with many adverse health effects, including premature deaths
- Assumed diesel PM and PM_{2.5} have equal toxicity

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But there is another important aspect regarding the toxic effects of diesel PM. It is a component of ambient PM_{2.5}, and PM_{2.5} is associated with non-cancer effects, including hospitalizations, work loss days, and even premature death.

Since large cohort studies are not possible with diesel PM in isolation, we assumed that diesel PM and PM_{2.5} have equal toxicity. This is based on the extensive animal toxicology literature, which leads to the conclusion that diesel PM is at least as toxic as the general ambient PM mixture.

Guest Speaker

- Professor Jonathan Samet, USC
 - Chair of U.S. EPA's Clean Air Scientific Advisory Committee
 - Chair of Department of Preventive Medicine at USC
 - Founding Director of Institute for Global Health at USC
 - Topic: Evidence for premature death from PM2.5 exposure

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Our guest speaker today is Dr. Jonathan Samet of the University of Southern California.

Dr. Samet, one of the world's leading public health experts, is the chair of the committee responsible for advising the U.S. EPA on ambient air quality standards, is the Chairman of the Department of Preventive Medicine at the Keck School of Medicine of USC, and is the founding director of the USC Institute for Global Health. He will be speaking on the evidence for premature death associated with PM2.5 exposure.

Presentation by Jonathan Samet

Placeholder (replace with your slides)

- Focus on epi data that show risk from PM2.5 exposure
 - NAAQS basis
 - Biological plausibility
 - total number of papers & funding commitment
 - uncertainties
- 7 minute presentation

Presentation Overview

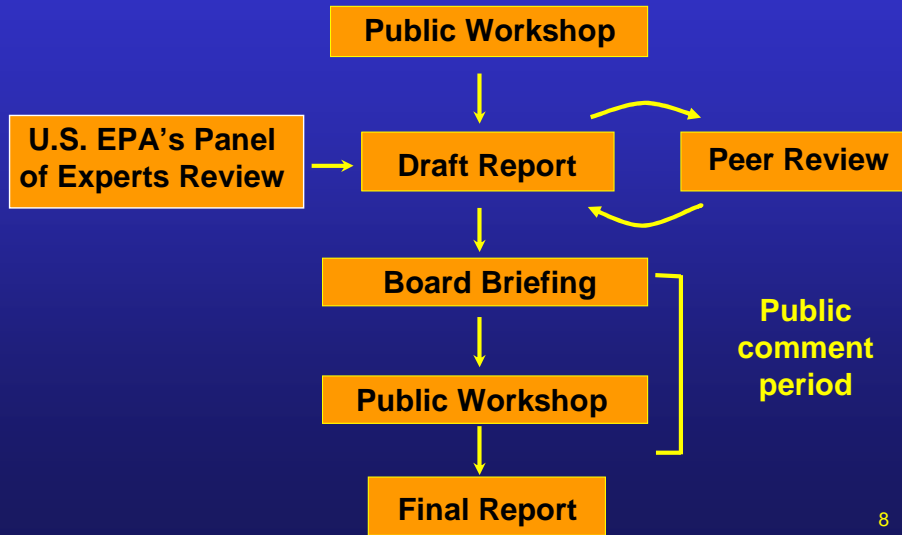
- Health effects of diesel PM
- Methodology for estimating premature deaths
- Control programs and PM trends

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At this point I would like to turn to the ARB staff report on the scientific literature supporting an association between PM_{2.5} and premature death and staff's update of the methodology used for quantifying the number of deaths that can be linked to PM_{2.5} exposure.

PM2.5 Exposure and Premature Death

Key Steps in ARB's Review of Health Literature



We began the 2-year process of updating the relationship between PM2.5 and premature death with a public workshop, followed by a review of the scientific literature.

Staff considered the results from an effort conducted by the U.S. EPA, which convened a panel of 12 experts to review the PM2.5 mortality literature and give their estimates of the magnitude of the effect, including the uncertainty of the estimates. As will be discussed in a later slide, ARB staff incorporated the panel's findings into its estimate.

The report was prepared in consultation with our advisors, peer reviewers and other experts and released for public comment. Staff then addressed and incorporated comments and suggestions into a final report released in October of last year.

ARB Mortality Report

- 78 peer-reviewed publications
- No books or opinion pieces
- Included all U.S. studies through August 2008

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In the PM2.5 mortality report, staff considered a total of 78 peer-reviewed publications. Staff did not include secondary literature, such as books or opinion pieces. All relevant peer reviewed studies were included in the report that were published through August of 2008. Some of the studies gave estimates higher than staff's recommendation, others gave lower estimates. Each was included and evaluated for the report.

Peer Review Evaluation

Advisors

- Dr. Jonathan Levy, Harvard University
- Dr. Bart Ostro, Office of Environmental Health Hazard Assessment
- Dr. Arden Pope, Brigham Young University

UCOP Peer Reviewers

- Dr. Jeffrey R. Brook, Environment Canada
- Dr. Mark D. Eisner, UC San Francisco
- Dr. Richard C. Flagan, California Institute of Technology
- Dr. Alan E. Hubbard, UC Berkeley
- Dr. Joel D. Kaufman, University of Washington
- Dr. Joel D. Schwartz, Harvard University

Additional Peer Reviewer

- Dr. Philip Hopke, Clarkson University

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In drafting the report, staff worked with the well-known epidemiologists and air pollution scientists listed on this slide who served as advisors and peer reviewers throughout the project. After considering the full range of studies, the methodologies and results presented in the report were endorsed by these advisors and reviewers.

The PM2.5 Mortality staff report went through formal, independent, peer review organized by the University of California Office of the President, and did not rely upon the health research or original work of ARB staff. However, concerns did arise earlier this year about the credentials and honesty of the report's coordinator. Therefore, in late April we asked all of the advisors and external reviewers to re-review the report. Nine of the ten responded and confirmed their original comments on the report. Despite continued attempts, we have not heard from the tenth reviewer. Therefore, we continue to be confident of the validity of the conclusions of the PM2.5 Mortality staff report.

How Was ARB's Estimate Developed?

- Pooled estimates from independent panel of 12 leading experts
- Most weight given to American Cancer Society and Six Cities cohorts
 - Includes LA study with improved exposure methodology

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ARB's estimate of the relation between PM_{2.5} and premature death is a compilation of estimates from the U.S. EPA panel of experts. It is not derived from a single study.

Each member of the expert panel was free to use any study they wanted to consider. The expert panel put most weight on studies using the American Cancer Society and Six Cities cohorts. Eight of the 12 U.S. EPA experts included a study done in Los Angeles with the ACS cohort to inform their estimate.

Public Health Statements

- American Medical Association
 - "... AMA support efforts to significantly reduce particulate air pollution by reducing the amount of particulate matter from diesel sources ..."
- American Heart Association
 - "... epidemiological studies conducted worldwide have shown a consistent, increased risk for cardiovascular events, including heart and stroke deaths, in relation to short- and long-term exposure to present-day concentrations of pollution, especially particulate matter."
- World Health Organization
 - "The effects of PM on health occur at levels of exposure currently being experienced by most urban and rural populations in both developed and developing countries. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer."

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The ARB is not alone in recognizing the public health threat posed by particulate matter. The American Medical Association, the American Heart Association, and the World Health Organization all have issued statements acknowledging the link between PM and adverse health outcomes, particularly cardiovascular and respiratory diseases.

Quantified PM2.5 Health Effects

- Premature death
- Hospital admissions
 - Respiratory illnesses
 - Cardiovascular illnesses
- Acute bronchitis
- Asthma and other lower respiratory symptoms
- Minor restricted activity days
- Work loss days

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In addition to premature death, a number of other health impacts associated with exposure to PM2.5 have been well documented. This slide lists the additional health endpoints which ARB typically quantifies and uses in its regulatory process.

Additional PM2.5 Health Effects

- Non-fatal heart attacks
- Infant death
- Low birth weight, premature birth
- Emergency room visits for asthma
- Exacerbation of asthma
- Chronic bronchitis

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...But, many more health effects associated with exposure to PM2.5 have also been reported, which are shown on this slide. We do not quantify these health impacts because we feel that the epidemiologic studies are not consistent enough to warrant a quantitative analysis. Nevertheless, these studies add to the weight of evidence of the adverse health impacts associated with PM2.5.

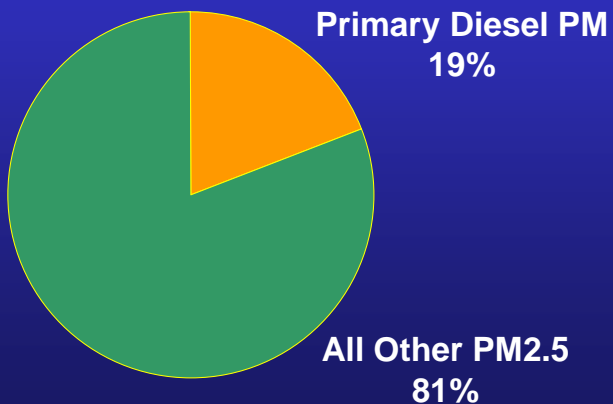
PM Reductions Improve Public Health

- Steel mill closure in Utah Valley
 - Reduced hospital admissions and deaths with reduced exposure
- Life expectancy and PM_{2.5} levels in the United States
 - 0.61 year increase in life expectancy for every 10 µg/m³ reduction
- Children's Health Study in California
 - Improved lung function growth in children moving from higher to lower pollution area⁵

While scores of studies have shown an increase in adverse health effects from increased PM_{2.5} exposure, the converse has also been observed— that is, a decrease of adverse health effects from (a) lower exposure. Studies of reductions of specific sources of pollution over an interval provide particularly strong evidence of a causal relationship because they evaluate the effects on health by reducing exposure.

This slide lists a few of the major studies that have shown improved health following reductions in particulate matter. These studies showed declines in deaths or diseases and include a landmark study on children's health that was funded by the ARB.

Risk from Diesel PM Exposure



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The adverse health effects listed in the last two slides are from PM2.5 exposure. But as discussed earlier, diesel PM is a component of the ambient mix of PM2.5, so a portion of the health impacts linked to PM2.5 exposure can be ascribed to diesel PM. With the assumption that diesel PM and ambient PM2.5 are equally toxic, ARB staff have calculated that 19% of the risk from PM2.5 exposure is from primary diesel PM. The translation of this risk into estimates of premature death and illness are shown in the next slide.

Annual Statewide Diesel PM Health Impacts

Health Endpoint	Mean (cases)	Range (cases)
Mortality	3,500	1,000 – 6,400
Hospital Admissions, Cardiovascular	740	480 – 1,100
Hospital Admissions, Respiratory	390	190 – 600
Lower Respiratory Symptoms	56,000	22,000 – 90,000
Acute Bronchitis	4,700	0 – 10,000
Minor Restricted Activity Days	2,100,000	1,700,000 – 2,400,000
Work Loss Days	350,000	300,000 – 410,000

Year 2005 emission inventory

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Listed in this slide are the annual health impacts associated with diesel PM exposure for the year 2005.

The impacts are substantial, but these numbers are expected to decrease, as regulatory actions by the Board result in a reduction in ambient levels of diesel PM.

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In fact, emissions reductions have already been realized as a result of the Board's aggressive diesel PM control programs. These programs and the resulting improvements in air quality are the focus of the next few slides.

Progress: New Engines and Fuels

Major Task	Action	Adoption status
New engines	Truck standards reducing NOx/PM by 90% (2007-10)	Complete
	Off-road equipment engine standards reducing NOx/PM by 90% (2011-15)	Complete
	Locomotive/harbor craft standards (EPA)	Complete
Fuels	Ultra-low sulfur diesel, on- and off-road	Complete
	Ship auxiliary engines	Complete
In-use compliance/enforcement	On-Board Diagnostics for heavy trucks	Complete
	In-use testing and recall program	Complete

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For more than a decade the Board has consistently reduced diesel PM emissions. From listing diesel exhaust as a carcinogen to implementing the Goods Movement Plan, to adopting the Truck and Bus Rule – the Board has led the nation with health-based strategies to reduce diesel PM emissions and exposure.

Actions include emission limits on new engines and improvements on fuels.

Progress: Existing Engines

Major Task	Action	% of PM	Cost (millions)	Adoption Status
Clean-up existing engines	Urban transit buses	<1	122	Complete
	Trash trucks	2	155	Complete
	Portable equipment	3	350-420	Complete
	Stationary engines	2	47	Complete
	Cargo handling equipment	<1	71	Complete
	Municipal fleets	<1	157	Complete

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...And also include cleaning up existing engines, as show in this slide and the next.

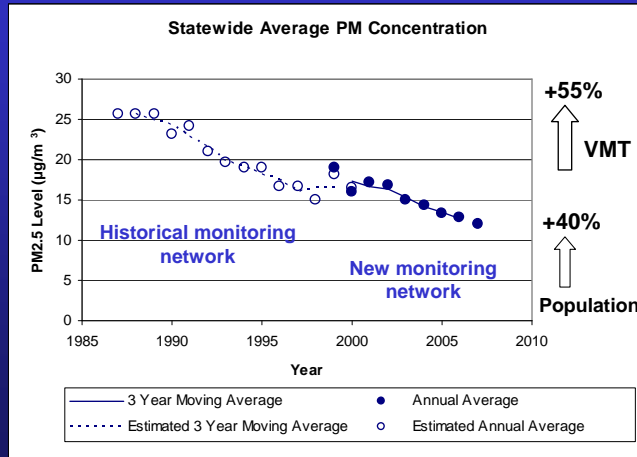
Progress: Existing Engines

Major Task	Action	% of PM	Cost (millions)	Adoption Status
Clean-up existing engines (cont.)	School buses	<1	200	Prop 1B
	TRUs	2	87-156	Complete
	Idling limits	1	Savings	Complete
	Stationary ag. engines	1	34-42	Complete
	Aux. engines OGV	3	165-171	Complete
	Port trucks, ships	9	400	Prop 1B
	Off-road non-ag.	30	3200	Complete
	Private trucks	37	5500	Complete
	Ag. equipment	8		2010

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Staff will continue to seek opportunities to reduce exposure to diesel PM in the future, as well.

Trend in Statewide Annual PM2.5 Concentration



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This graph shows the population-weighted annual average PM2.5 concentration for the entire state from 1987 to 2007.

There is about a five percent improvement in air quality per year, due primarily to the Board's motor vehicle and diesel engine control programs, as well as the continued implementation of stringent local district rules on combustion sources. This improvement has occurred even with large increases in both the number of vehicle miles traveled and the population over the last twenty years.

Additional PM Reductions Are Needed

- Reduce premature deaths
- Reduce diesel PM emissions by 85% by 2020
- SIP attainment in South Coast and San Joaquin Valley
- Attain increasingly tighter federal PM_{2.5} standards

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As much as the Board has accomplished, there continues to be a need to reduce PM further.

The best available science indicates that at the current levels of PM_{2.5} in California, we continue to experience thousands of premature deaths annually.

As part of the Diesel Risk Reduction Plan and the Goods Movement Emission Reduction Plan, ARB committed to reducing diesel PM emissions and cancer risks by 85% by 2020.

The Board also continues to reduce PM_{2.5} levels in order to meet current State Implementation Plan attainment deadlines in the South Coast and San Joaquin Valley, and in anticipation of increasingly tighter federal PM_{2.5} standards.

Research to Address Remaining Issues

- U.S. EPA PM Centers
 - Ultrafine PM
 - Biological plausibility
 - Toxic components of PM
 - Pollutant mixtures
- CA-specific studies
 - California Teachers cohort
 - American Cancer Society cohort

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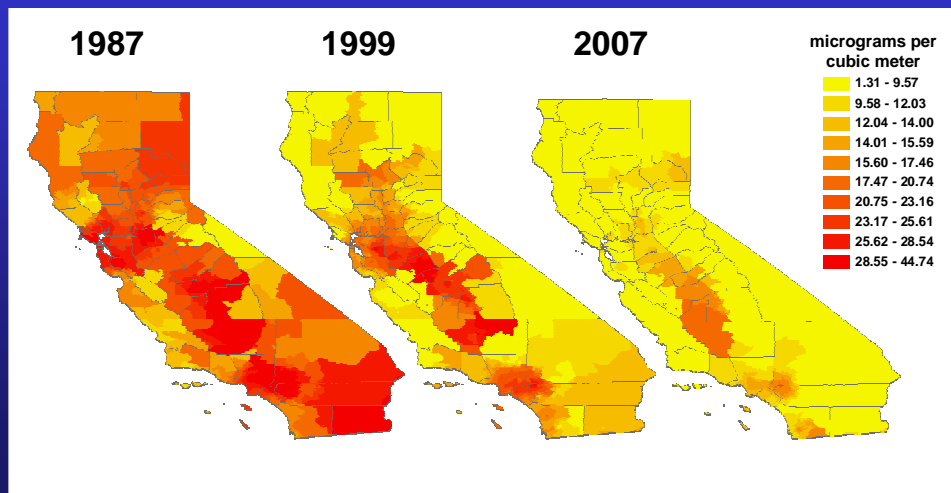
Although the link between PM_{2.5} and adverse health outcomes is well established, research is needed to address several important issues.

The U.S. EPA established five PM centers, including the Southern California Particle Center, and the San Joaquin Valley Aerosol Health Effects Research Center, to investigate the health effects of PM including ultrafine PM, biological plausibility, toxicity of components of PM, and pollutant mixtures. These centers each receive 8 million dollars over five years.

ARB is funding two major California-specific studies including the California Teachers Cohort, which is investigating the link between PM_{2.5} and premature death among 130,000 female teachers. ARB has also funded an ongoing analysis of the California residents enrolled in the American Cancer Society cohort.

As this on-going research continues, we are committed to updating ARB's estimate of PM-related death when new data become available.

PM2.5 Exposure



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Lastly, there has been a dramatic reduction in PM2.5 over the last 20 years. Our progress in reducing particles is shown in this series of maps of PM2.5 concentration for the years 1987, 1999, and 2007. As shown in the key on the right, the darker the color, the higher the PM2.5 concentration.

Throughout California, we can see significant reductions in PM2.5 exposures, especially in major air basins. In fact, the rates of PM2.5 reductions in California are among the most striking in the nation.

And, as the ARB continues its PM control program to help meet Californian's clean air goals, we expect to see a sustained downward trend in ambient PM2.5 concentrations, with associated improvements in public health.

This concludes my presentation. Thank you for your attention, and we would be happy to answer any of your questions.